OPEN-FILE REPORT 98-09

SEISMIC HAZARD EVALUATION OF THE MINT CANYON 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, *STATE GEOLOGIST*

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PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
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Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Mint Canyon 7.5-Minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Mint Canyon 7.5-Minute Quadrangle, Los Angeles County, California

By
Wayne D. Haydon

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Mint Canyon 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles region was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Mint Canyon Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although the selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Mint Canyon Quadrangle covers approximately 62 square miles of land in west-central Los Angeles County. Parts of the City of Santa Clarita, including the communities of Newhall and Canyon Country that lie primarily west of the Antelope Valley Freeway (State Highway 14), cover the central and western portion of the quadrangle. The city also extends to an area that straddles Sand Canyon Road, south of the freeway. Canyon Country (Solemint Junction), near the center of the quadrangle, lies about 27 miles north-northwest of the Los Angeles Civic Center. The remainder of the land within the quadrangle is either comprised of unincorporated county land or lies within the Angeles National Forest, except for a small part of Placerita Canyon State Park that lies along the southern boundary. The primary access to the area is via the Antelope Valley Freeway (State Highway 14), which crosses the quadrangle from the southwestern corner to the eastern boundary. East of Solemint Junction, which is located near the freeway crossing of the Santa Clara River, the freeway follows the course of the river, which flows across the center of the quadrangle. West of Solemint Junction, Soledad Canyon Road provides access from Saugus to the west. Sierra Highway, which follows Mint Canyon, crosses the entire quadrangle from southwest to northeast.

The topography of the quadrangle is dominated by irregular, badland to mountainous, brush-covered terrain. Numerous canyons dissect the mountains. Some of the larger canyons, such as Sand, Mint, and Tick canyons, are tributary to the Santa Clara River. Bouquet Canyon, which itself has tributaries including Texas, Vasquez, and Plum canyons, exits the quadrangle in the central part of the western boundary and joins the Santa Clara River in the Newhall Quadrangle. Placerita Canyon lies close to the southern boundary of the quadrangle.

Residential and commercial development, primarily of the lower-lying canyon-bottom lands, has replaced agricultural and grazing land uses within the area in recent decades. Modern development is characterized by mass grading of the hillside areas at a large scale. The remainder of the area is largely unoccupied, although agricultural activities, small ranches, oil fields, parkland, and National Forest lands are scattered across the quadrangle.

GEOLOGIC CONDITIONS

Structural and Depositional Setting

The Mint Canyon Quadrangle lies within the Transverse Ranges geomorphic province of southern California, which is characterized by a complex series of mountain ranges and valleys with dominant east-west trends. Within the Mint Canyon Quadrangle, the Ventura and Soledad depositional basins are juxtaposed along the San Gabriel Fault, a major structural boundary feature that crosses the southwest quarter of the quadrangle. Rocks that accumulated in the Ventura Basin are exposed southwest of the San Gabriel Fault and rocks that accumulated in the Soledad Basin are exposed northeast of the fault. Pre-Cenozoic igneous and metamorphic rocks are exposed along the northern, southern, and southeastern margins of the quadrangle. Most of the rocks exposed within the quadrangle, however, consist of a thick section of fluvial and lacustrine beds that comprise the middle to late Miocene Mint Canyon Formation. North of the San Gabriel Fault these Soledad Basin rocks are overlain, locally, in the western part of the quadrangle by marine strata of the Castaic Formation. Near the eastern boundary of the quadrangle the Mint Canyon Formation was deposited upon older sedimentary rocks belonging to the Tick Canyon and Vasquez formations (Saul and Wootton, 1983).

Nonmarine, Plio-Pleistocene arkosic sandstone, siltstone, and conglomerate beds of the Saugus Formation and Pleistocene, locally coarsely conglomeratic, Pacoima Formation are widespread west of Mint Canyon and south of the San Gabriel Fault. Terrace deposits, older colluvial and fan deposits, and younger alluvium and slope wash are also abundant within the map area. Quaternary alluvium is common in the canyon bottoms and valleys of the streams that are tributary to the Santa Clara River.

Surface Geology

The digital geologic map used to evaluate the geologic units of the study area for liquefaction was taken primarily from Yerkes (1996), who compiled and digitized the large-scale geologic maps of Saul and Wootton (1983) and Saul (1985). Other geologic maps reviewed for this project include: Oakeshott (1958), Winterer and Durham (1962), Weber (1982), and Dibblee (1996). Only the types of geologic units that are generally susceptible to liquefaction were evaluated. Such units include the Quaternary alluvial and young fluvial sedimentary (flatland) deposits and artificial fill. The geologic maps from Saul and Wootton (1983) and Saul (1985), which were compiled and digitized by Yerkes (1996), provided the most detail in the mapping of the Quaternary fluvial and alluvial flatland sedimentary deposits. However, the mapping of the Quaternary deposits was inconsistent across the map and was not considered detailed or accurate enough to use for evaluating the liquefaction susceptibility of the different Quaternary units exposed in the Mint Canyon Quadrangle. Therefore, a reconnaissance geologic map for use in this project was prepared that focused upon differentiating the Quaternary fluvial and alluvial flatland sedimentary deposits. The mapping was based on the evaluation of flatland geomorphology, aerial photograph interpretation, examination of soil survey maps (Woodruff and others, 1966), review of subsurface borehole logs and field reconnaissance. The reconnaissance geologic map differs from the map of Yerkes (1996), in that much of the bedrock-alluvium contact was remapped in greater detail and some of the unit designations were reassigned, based upon a reevaluation of the age of each unit or its geomorphic expression. The geologic units were also grouped more consistently.

Quaternary fluvial and alluvial flatland sedimentary deposits were mapped in the main and tributary valleys and canyons of the Santa Clara River Valley, Haskell Canyon, Bouquet Canyon, Texas Canyon, Vasquez Canyon, Plum Canyon, Mint Canyon, Baker Canyon, Tick Canyon, Oak Spring Canyon, Sand Canyon, Iron Canyon and Placerita Canyon. Most of the soil series developed on the deposits, interpreted in the mapping for this project as late Holocene fluvial and alluvial units, are those generally considered to overlie Holocene geologic units (Tinsley and Fumal, 1985).

Active washes were mapped along the incised channels in the main and tributary canyons and valleys. The most prominent wash in the study area is mapped along the Santa Clara River, where the wash generally occupies the approximate center of the Santa Clara River Valley. The washes are partially filled with sand and gravel deposited as bedload by wet-season stream flow. These washes are incised into the late Holocene fluvial deposits of the valley floors.

Active fluvial deposits were mapped as small, planar, non-incised or slightly incised deposits, generally on the smaller tributary canyon floors. Active fan and alluvial apron deposits were mapped as small- to moderate-size, respectively, convex- (downslope) outward fan-shaped or planar, non-incised or slightly incised deposits emanating from small drainages onto the small- to moderate-size tributary valley floors.

Included with the fans are small areas of colluvium that were not mapped separately for this project. In Yerkes (1996) most of the unnamed smaller canyons that are tributary to the larger named canyons were mapped as colluvium. Active alluvial fans were mapped emanating from some of the smaller tributary canyons in Yerkes (1996) but were identified more frequently emanating from more of the smaller tributary canyons during mapping conducted for this project.

Late Holocene fluvial deposits were mapped along the planar, slightly to moderately incised, gently downstream-sloping floors of all the named main and most of the tributary canyons and valleys. The largest of these deposits was mapped in the unnamed tributary canyons and valleys along: the southern margin of the Santa Clara River Valley at the confluence of the unnamed canyons in the western half of the study area; along the northern margin of the Santa Clara River Valley at the confluence of the unnamed canyons in the eastern half of the study area; along the northern margin of Bouquet Canyon; and along the northern margin of Mint Canyon. In Yerkes (1996), many of the larger named canyons are mapped as flood plain deposits. These include the Santa Clara River Valley, Bouquet Canyon, Haskell Canyon, Texas Canyon, Vasquez Canyon, Plum Canyon and the northern part of Mint Canyon. Most of the alluvial deposits in the unnamed tributary canyons as well as Baker Canyon, Sand Canyon, Iron Canyon, much of Oak Spring Canyon, the southern part of Mint Canyon and Placerita Canyon are shown in the map of Yerkes (1996) as colluvium.

Late Holocene alluvial fans were mapped as the convex-outward fan shaped deposits that slope toward the main trunk stream and valley floor. These deposits form individual fans or coalesce to form alluvial aprons along the margins of the main canyons and valleys and emanate from some of the tributary canyons. These alluvial fans and aprons were identified along the margins of nearly all the named main valleys. The largest deposits are: along the eastern margin of Bouquet Canyon between Vasquez and Plum canyons; along the northern margin of the Santa Clara River Valley at the confluence of Mint Canyon; and the unnamed canyon west of Mint Canyon and Sand Canyon. The alluviated flatlands upslope from the fans in the tributary valleys were mapped as active or late Holocene fluvial deposits.

Where water levels are high, younger Holocene fluvial and alluvial deposits are generally considered to have moderate to high liquefaction susceptibility (Youd and Perkins, 1978).

Terrace deposits (Qt) were mapped on erosional surfaces in the upland areas on the map of Yerkes (1996) and during the detailed mapping for this project.

Older colluvium (Qco) and colluvium (Qc) was mapped as scattered surficial deposits in the upland areas on the map of Yerkes (1996) and during the detailed mapping for this project.

Artificial fill was mapped, both by Yerkes (1996) and during the mapping for this project, in the south and west end of Bouquet Canyon and Plum Canyon, and the south half of Tick Canyon. The fill is generally thin and was placed during the grading for relatively recent, large residential and commercial developments.

Subsurface Geology and Geotechnical Characteristics

Information on the subsurface geology and geotechnical characteristics of the flatland deposits was obtained from borehole logs collected from reports on work done in the study area. For this investigation 119 borehole logs were collected from the files of the Los Angeles County Department of Public Works; California Regional Water Quality Control Board, Los Angeles Region; and private consultants. However, the boreholes are too widely spaced and unevenly distributed to adequately describe the subsurface geology or geotechnical properties of the flatland deposits. All of the moderate to large alluviated canyons contain very few to no boreholes at all. Evaluation of borehole logs and reconnaissance mapping of the younger deposits indicate that the fluvial and alluvial deposits consist primarily of coarse-grained sediments, mostly sand, silty sand and gravel, with interbeds of silt and clay. These deposits are discussed below, grouped into two locales or physiographic environments, based on the relative proportions of the coarser-grained sediment types (sand, silty sand, and gravel) to the finer-grained material (silt and clay).

Data from borehole logs were entered into the DMG Geographic Information System (GIS) database. Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Construction of cross sections from the borehole logs, using the GIS, enabled the correlation of soil types from one borehole to another and outlining of areas of similar soils.

Santa Clara River Valley, Placerita Canyon and associated larger alluvial canyons

The gently sloping, planar valley floors of the Santa Clara River Valley, Bouquet Canyon, Mint Canyon, Tick Canyon, Oak Spring Canyon, Sand Canyon, and Placerita Canyon are underlain by fluvial sediments deposited by the streams flowing down the valleys. These areas were generally mapped as floodplain (Qfp) in Yerkes (1996), except in Placerita Canyon were these deposits were mapped as colluvium (Qc). These deposits consist primarily of brown, dark brown, gray-brown and green-gray, well-graded, fine- to coarse-grained and poorly graded, fine-, fine- to medium- and medium- to coarse-grained sand. Deposits are generally described as gravelly, with a trace of scattered or occasional fine- or fine- to medium-grained gravel and often with pebbles, cobbles and boulders. The very coarse-grained clasts occur primarily as individuals surrounded by sand and rarely as interbeds. In some places, the sand units are gravel free.

The sand deposits contain interbeds of brown, light brown, yellow-brown and red-brown, fine-, fine- to medium-, medium- to coarse-, fine- to coarse- and coarse-grained silty sand. Gravel contents are generally described as trace, slightly, or some cases, fine- or fine- to medium-grained gravel with some of the silty sands containing occasional pebbles and cobbles and some without gravel. In general, the silty sand interbeds appear to contain a smaller percentage of gravel, pebbles and cobbles, with a larger percentage that do not contain gravel, compared to the more abundant sand units.

Occasionally, thin interbeds were identified of brown, gray-brown, green-brown and dark gray, sandy silt or clay. The sands are generally fine or fine to coarse with none to a trace or little fine gravel.

The sands and silty sands are generally described as loose in the very shallow deposits with the deeper deposits described as medium dense to very dense. Deposits containing gravel, pebbles, or cobbles are typically described as denser then deposits without or with apparently smaller percentages of the very coarse clasts. Along the Santa Clara River Valley, over 58% of the measured or corrected SPT N values are greater than 50 blows, in the very dense range, with 22% of the N values between 31 and 50 blows, in the dense range and about 18% with blow counts between 11 and 30, in the medium dense range. Along Bouquet Canyon, Plum Canyon and Texas Canyon, 25% of the N values exceed 50 blows, in the very dense range, with about 50% in the 11 to 30 blow count range and 25% of the N values are between 31 and 50 blows, in the dense range. In the silt or clay interbeds the N values were less than 8, generally in the medium stiff range. However, as described in the Quantitative Liquefaction Analysis section, the gravel clasts probably cause many of the N values in the sand and silty sand units to be too high.

Dry unit weights in the sands and silty sands along Bouquet Canyon, Plum Canyon, and Texas Canyon, were between 101 and 110 pounds per cubic foot (pcf) for over 50% of the soil samples with over 30% in the 111 to >120 pcf range and 13% in the 91 to 95 pcf range. Moisture contents were generally below 15% but varied up to about 20 %. No dry unit weight values were identified for the Santa Clara River Valley.

Based on the age and depositional environment of this deposit, the generally gravelly sand and silty sand are interpreted as being loose to medium dense.

Alluvial fans flanking the larger alluvial canyons and smaller alluvial canyons

The gently sloping, small- to moderate-size convex-outward (downslope) fan-shaped or planar surfaces emanating from small-to moderate-size drainages onto the small and the main tributary valley floors are underlain by active alluvial fan and alluvial-apron deposits. These deposits were typically mapped as colluvium (Qc) or, locally, as fans (Qf) in Yerkes (1996). These deposits consist primarily of brown, light brown, gray-brown, and rarely yellow-brown and red-brown, silty sand. The sand is fine to medium, fine to coarse, or fine grained. Gravel contents are generally described as trace, few, slightly, or gravelly, with much of the silty sands containing pebbles and cobbles and some without gravel. In general, the silty sand deposits appear to have a similar gravel content to the silty sand interbeds in the larger alluvial valleys.

The silty sand deposits contain interbeds of brown, light brown, gray-brown, yellow-brown and red-brown, fine-, fine- to medium-, medium- to coarse- and fine- to coarse-grained sand. Gravel contents are generally described as gravelly, slightly gravelly or trace with much of the sands containing pebbles and cobbles, rarely without gravel. In general, the sand interbeds appear to have a similar gravel content to the sand deposits in the larger alluvial valleys.

Thin interbeds of dark brown or brown, sandy silt were occasionally identified. The sand sizes, however, were not specified and the interbeds apparently contain no gravel.

The sands and silty sands are variously described as firm, soft to firm, moderately loose, and moderately firm, as well as loose, in the very shallow deposits. In the deeper deposits these sands are described as medium dense to dense and, rarely, very dense. In the tributary canyons to the Santa Clara River Valley, Plum Canyon, Bouquet Canyon, and Texas Canyon about 27% of the measured or corrected SPT N values are greater than 50 blows, in the very dense range, with 29% of the N values between 31 and 50 blows, in the dense range and about 41% with blow counts between 11 and 30, in the medium dense range. However, as described in the Quantitative Liquefaction Analysis section, the gravel clasts probably cause many of the N values in the sand and silty sand units to be too high. In the tributary canyons to the Santa Clara River Valley at the eastern margin of the study area, to Tick Canyon and throughout the unnamed canyons west of Tick Canyon on the north side of the Santa Clara River Valley, 74% of the N values were between 5 and 20 blows, in the loose to the lower half of the medium dense range, with the remaining 26% fairly evenly spread out between 21 and >50 blows, in the upper half of the medium dense to the very dense range. These N values are in the range expected for deposits of the interpreted age and depositional environment.

Dry unit weights of the silty sands and sands in the tributary canyons to the Santa Clara River Valley, to Plum Canyon, to Bouquet Canyon and to Texas Canyon were between 106 and >120 pcf for 77% of the soil samples with the remaining 23% primarily between 91 and 106 pcf. In the tributary canyons to the Santa Clara River Valley at the eastern margin of the study area, to Tick Canyon and throughout the unnamed canyons west of Tick Canyon on the north side of the Santa Clara River Valley, dry unit weights are generally lower with 95% of the values between 91 and 115 pcf, 5% with values between 116 and >120 pcf. Dry unit weights of the silt interbeds were generally between 91 and 105 pcf, but ranged from about 86 to >120 pcf. Moisture contents of the silty sands, sands and silts were generally below 10% but ranged up to about 25%.

Based on the age and depositional environment of this deposit the generally gravelly silty sand and sand are interpreted as being loose to medium dense.

GROUND-WATER CONDITIONS

Ground-water conditions were investigated to evaluate the depth to saturated sediments. Saturated conditions reduce the normal effective stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of liquefaction (Youd, 1973). A ground-water evaluation of alluviated valleys and canyons in the Mint Canyon Quadrangle was performed to document the historically highest ground-water levels. For liquefaction zoning purposes, areas characterized by historical ground-water depths of 40 feet or less are considered for liquefaction analyses.

Ground-water depth data were obtained from published ground-water investigations (Robson, 1972) that summarized ground-water conditions in the study area for the years 1945 to 1967, annual maps of the ground-water elevation contour in the alluvial valley deposits prepared by the Los Angeles County Department of Public Works, Hydraulic/Water Conservation Division (LACDPW) for the years 1945 through 1995 (LACDPW, 1995), and from the collected geotechnical and environmental borehole logs.

Depth- to-Ground Water Contour Map Preparation

Interpretation of Robson (1972) and LACDPW (1995) indicates that no one single year's ground-water elevation contour map of the alluvial valley aquifer represents the shallowest recorded ground-water levels for all of the study area. The shallowest recorded ground-water levels in various parts of the study area occurred in different years. A ground-water elevation contour map of the shallowest recorded water levels for the study area was compiled from the LACDPW ground-water contour maps from various years that represented the shallowest ground-water identified in parts of the study area. The regions of the study area and the year of the ground-water elevation contour map used to compile the ground-water map are as follows: in the Santa Clara River Valley, 1969 with the 1,700 foot contour from 1977 and the 1,650 and 1,675 foot contours from 1967; in Bouquet Canyon, 1983, with the 1,625 foot contour from 1975; in Sand Canyon and Oak Spring Canyon, 1983 with the 1,775 and 1,800 foot contour from 1978; in Mint Canyon, 1993 with the 1,775 through 1,925 foot contours from 1995; in Placerita Canyon, 1995. The depth to the shallowest recorded ground-water map is presented on Plate 1.2.

The depth-to-ground water contour map (Plate 1.2) was prepared by comparing the compiled shallowest ground-water elevations with the ground surface elevations. The applicability of this method to accurately depict alluvial ground-water conditions in the study area was evaluated by noting the depth to ground water in boreholes identified in the flatlands. These borehole ground-water depths were compared to the depth to ground water recorded on the LACDPW ground-water contour maps for the year the borehole was drilled. Generally, there was good agreement between the depth to ground water identified in boreholes drilled into the alluvium and the depth to ground water recorded in the LACDPW ground-water contour maps for the year the borehole was drilled.

However, some modifications were made to the compiled depth-to-ground water contour map to account for anomalies in the data and to make this map more accurately reflect the most likely ground-water conditions.

The depth to ground water in Sand Canyon is problematic. Inspection of the compiled ground-water contour map indicates that in Sand Canyon the depth to ground water is at a relatively constant depth equal to or less than 25 feet in the northern approximately 1.5 miles of the canyon, in Sections 23 and 26. The depth-to-ground water then descends toward the south to 50 feet within a distance of about 0.75 miles, in the southern portion of Section 35, then becomes shallower toward the south to a depth of 40 feet within less than 0.5 mile. Inspection of the LACDPW ground-water contour maps indicates this is a common ground-water pattern when ground water is shallow in the northern portion of the canyon. However, when ground water is deep in the northern portion of the canyon it also tends to be deep in the southern portion as well.

This deep ground water is peculiar because all the similar canyons in the study area have relatively shallow ground water. This deep measurement to ground-water level may be the result of the monitored well having been partially completed into the Mint Canyon Formation, which underlies the valley alluvium and is likely to have deeper ground water as identified in the Saugus Formation in other portions of the study area (Robson, 1972). The apparent deep ground water may result from the flow of ground water in the well from the alluvium to the underlying Mint Canyon Formation, and the subsequent drawdown in the well.

To investigate whether the apparent deep ground water was the result of wells monitoring bedrock instead of the alluvium, logs of wells in Sand Canyon were obtained from LACDPW and DWR and interpreted. Unfortunately, not all the logs of the wells LACDPW monitors to prepare the yearly ground-water contour maps were available. However, interpretation of the available logs and additional logs from DWR suggests that wells in the northern portion of the canyon monitor the ground water in the alluvium, whereas wells in the southern portion of the canyon monitor ground water primarily in the bedrock or both. This information suggests that the deep ground water recorded on the LACDPW ground-water contour maps for the southern part of Sand Canyon reflects wells in that area measuring the depth to ground water in the bedrock underlying the alluvium. Therefore, the depth to ground water in the liquefaction analysis for Sand Canyon was taken as 20 feet, which is the depth throughout most of the northern portion of the canyon.

Ground-water information was generally lacking in the many small and moderately sized, named and unnamed, alluvial valleys that are tributary to the main valleys of Bouquet Canyon, Mint Canyon, and the Santa Clara River Valley. These tributary canyons merge with the trunk valleys either directly onto the fluvial deposits of the valley floor or onto the alluvial fans emanating from the tributary valleys that flank the larger valleys. Ground-water data are lacking for the tributary canyons of Bouquet Canyon such as Texas Canyon, Vasquez Canyon, and Plum Canyon, the small tributary canyons to these canyons, as well as the many smaller, unnamed canyons that are tributary to Bouquet Canyon. There are no ground-water data for the tributary canyons of Mint Canyon, including Baker Canyon. Ground-water data are lacking for the tributary canyons of the Santa Clara River Valley, such as the unnamed canyons on the northern and southern margins of the valley, Oak Spring Canyon, and Tick Canyon. Ground-water data are also lacking for the eastern, narrow half of Placerita Canyon, and the large exposures of slopewash to the east of Placerita Canyon. The depth to ground water for the small and moderately sized, unnamed and named tributary canyons was taken as the depth to ground water identified or interpreted at the mouth of the tributary canyon where the canyon merges with either the main valley or the alluvial fans.

Ground-water information is also generally lacking in those portions of Quigley Canyon and Haskell Canyon that lie within this study area. The depth to ground water for these canyons was taken as the northernmost depth-to-ground-water contour identified in each of the valleys to the west of the study area in the Newhall Quadrangle.

Study Area Ground-Water Conditions

The historically shallowest ground-water levels are generally shallow across the study area with extensive areas of very shallow ground water along the larger, named canyons. The compiled ground water and interpreted depth-to-ground water maps are presented in Plate 1.2.

In Bouquet Canyon the depth to ground water is about 25 feet at the western boundary of the study area. The depth to ground water shallows to the north, up the canyon, to between 0 and 10 feet in Section 6, and is interpreted to be about 10 feet up the canyon from the western half of Section 5. In the unnamed canyons tributary and north of Bouquet Canyon in Sections 6 and 31 the depth to ground water is interpreted to be about 0 to 5 feet. In Texas Canyon, Vasquez Canyon, and the unnamed canyons tributary to Bouquet Canyon north of the western half of Section 5, the depth to ground water is interpreted to be about 10 feet. In Plum Canyon, the depth to ground water is interpreted to be less than 25 feet based on the ground-water depth in Bouquet Canyon at the confluence to the two canyons.

In Haskell Canyon and the unnamed tributary canyon the depth to ground water is interpreted to be about 25 feet, based on ground-water conditions identified to the west of the study area in the Newhall Quadrangle.

In Mint Canyon, the depth to ground water ranges from 0 to 20 feet. In the southern half of Mint Canyon and tributary canyons, in Sections 21, 15, 11, and 2, the depth to ground water is between 0 and 10 feet. Ground water along Mint Canyon in Section 1 and the tributary canyons in Sections 2, 35, and 36 deepens to 20 or 25 feet and then shallows up the canyon to 10 feet in Section 31. The depth to ground water is interpreted to be 10 feet for the remainder of Mint Canyon up the canyon in Sections 19 and 30, as well as in Baker Canyon, based on the ground-water depth in the main trunk of Mint Canyon.

Along the Santa Clara River Valley, the depth to ground water ranges from 5 to 25 feet. In the western half of the Santa Clara River Valley, the ground-water depth generally descends from 5 feet along the northern margin of the valley to 15 feet along the southern margin. At the confluence of the moderate-size, unnamed valley along the southern margin of the Santa Clara River Valley in Section 29, the ground-water depth descends to 25 feet and the ground-water depth in the unnamed valley is, therefore, interpreted to be less than 25 feet. The ground-water depth in the unnamed valley along the northern margin of the Santa Clara River Valley in Sections 16 and 17 is interpreted to be 5 feet, whereas the depth to ground water in the unnamed valleys along the southern margin of the Santa Clara River Valley in Sections 19, 20, 23, 27, 28, and 30 is interpreted to be 15 feet, based on the ground-water depth in the main trunk of the Santa Clara River Valley.

Along the western half of the eastern half of the Santa Clara River Valley, the ground-water depth is about 15 feet at the northern and southern valley margins and shallows to about 5 feet in the valley center. At the confluence of the Oak Spring Canyon the ground-water depth descends to 25 feet and the ground-water depth in Oak Spring Canyon is, therefore, interpreted to be less than 25 feet. The ground-water depth in the unnamed valleys along the northern margin of the Santa Clara River Valley in Sections 13 and 14 is interpreted to be 15 feet, based on the ground-water depth in the main trunk of the Santa Clara River Valley.

Along the eastern half of the eastern half of the Santa Clara River Valley, ground water deepens from about 10 feet toward the east to about 25 feet at the eastern boundary of the study area. The ground-water depth in Tick Canyon and the unnamed valley just to the east, along the northern margin of the Santa Clara River Valley, is interpreted to be 10 feet, based on the ground-water depth in the main trunk of the Santa Clara River Valley.

In Sand Canyon the depth to ground water descends from 10 feet at the northern end and along the eastern margin of the canyon towards the west and south to 25 feet in the southeastern corner of Section 26. The remainder of Sand Canyon to the south, as well as Iron Canyon, Gorman Canyon, Coyote Canyon, and Bear Canyon are interpreted as having a ground-water depth of less than 25 feet, as described in the Depth-to-Ground Water Contour Map Preparation section of this report.

In Placerita Canyon the ground-water depth is about 20 feet at the western study area boundary and shallows within about 600 feet to the east, upcanyon, to 10 feet. Ground water then deepens to 15 feet upcanyon in the west half of Section 5 and then shallows farther upcanyon to 5 feet in the east half of Section 5. The remainder of the upcanyon, narrow portion of Placerita Canyon is interpreted to have a ground-water depth of 5 feet. The depth to ground water in the tributary canyon in Section 32 is interpreted to be about 10 feet, based on the ground-water depth in the main trunk of Placerita Canyon.

The large exposures of slopewash to the east of Placerita Canyon and small alluvial canyons along the western and eastern study area boundaries are interpreted to have a depth to ground water of about 10 to 20 feet.

In Quigley Canyon, the depth to ground water is interpreted to be less than 40 feet based on ground-water conditions identified to the west of the study area in the Newhall Quadrangle.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) apply a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the Mint Canyon Quadrangle, peak accelerations of 0.49 to 0.767 g resulting from earthquakes of magnitude 6.6 to 7.8 were used for liquefaction analyses. The PGA and magnitude values were derived from maps prepared by Petersen and others (1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Quantitative Liquefaction Analysis

Quantitative analysis of liquefaction potential was performed using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and Harder, 1990; Youd and Idriss, 1997). The analysis is based on standard penetration test (SPT) results, ground-water conditions, unit weight/moisture content measurements, and sediment grain size analysis. Earthquake data required in the analysis are moment magnitude and PGA.

Of the 119 borehole logs in the alluvial flatland compiled for this study, 32 logs had blow counts from Standard Penetration Tests or from tests that could be converted to SPT's, and fewer included all of the required information (SPTs, density, water content, percentage of silt and clay size grains) for a complete Seed Simplified Analysis. For those boreholes where SPTs were recorded, the liquefaction analysis was conducted using either data from each borehole or extrapolated from nearby boreholes or in similar materials.

For each borehole where SPT's were conducted, those values along with density, moisture content, grain size information and ground-water levels were extracted from the database. These data were then processed through a program developed by DMG staff for liquefaction analysis by the Seed Simplified Procedure. The results of the analyses are discussed below for each geologic material type.

The liquefaction evaluation procedures where developed primarily for clean sands and silty sands. Results depend greatly on the accurate evaluation of the in-situ density of soils as measured by the number (N) of soil penetration blow counts using a soil penetration test (SPT) sampler or a cone-penetrometer test (CPT). However, most of the Holocene fluvial and alluvial deposits in the Mint Canyon Quadrangle contain a significant gravel component. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of such soils would allow the dissipation of pore water pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during many earthquakes and recent laboratory studies have shown that certain gravelly soils are susceptible to liquefaction.

Field and laboratory studies regarding the liquefaction susceptibility of gravelly sands (Sy and others, 1996: Budiman and Mohammadi, 1996; Harder and Seed, 1986; Ishihara, 1995; and Evans and Zhou, 1995) indicate that sandy and silty gravels have significantly lower permeabilities than clean gravels and, therefore, do not dissipate excess pore pressures quickly enough to prevent liquefaction. Boundary drainage conditions were found to be important. For example, the presence of an impervious surface layer can impede drainage leading to liquefaction of underlying gravelly soils.

Liquefaction susceptibility is dependent on the gravel content of the soil, the presence of a liquefiable sand lens in the gravelly unit, and, in matrix supported gravels, on the density of the matrix sand. The liquefaction susceptibility of sand and gravel composites may decrease considerably with increasing gravel content. Gravel contents of less than 20 to 25% were found not to decrease liquefaction susceptibility and may increase susceptibility, whereas deposits with 40 to 60% gravel and a moderately dense sand matrix had the liquefaction susceptibility of dense sand (Evans and Zhou, 1995). Soils with gravel contents of up to 57 percent have been documented as having liquefied during the 1993 Borah Peak earthquake (Harder, 1994). In general, loose to medium dense gravelly sands, with equivalent sand SPT N values less than about 20 are susceptible to liquefaction.

SPT- or CPT-derived density measurements in gravelly soils are unreliable and generally too high because the gravel clasts are too large to fit into the sampler or they bridge the opening of the sampler. The sampler tends to bounce on the clasts in such gravels. Field methods developed to evaluate the liquefaction susceptibility of gravelly soils include:

a) using the lowest recorded N value as a representative of the gravelly soil statum;

b) recording N values for small-depth increments to assess the effect of gravel clasts as a basis for rejection or acceptance of the N value or to infer the N value for the finer-grained matrix of the gravelly deposit;

c) or to use a large-scale penetration test such as the Becker Hammer Drill, adjust the N values from the Becker test using established relationships to the SPT N values, and then using the adjusted N values in the liquefaction evaluation as for sand.

The quantitative liquefaction analysis performed for this study was complicated by the gravel component of many of the soils. Many of the N values from the gravelly sand strata are suspected of being too high, for the reasons discussed above. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To overcome this problem, the computerized analysis was reinterpreted to account for the gravel content. The log of each borehole was compared to the liquefaction analysis to evaluate if the results of the analysis appeared to have been affected by N values that are too high due to the presence of gravel. Correlations were made between boreholes to identify potentially liquefiable units where the N values appeared to have been affected by gravel content with areas where the N values do not appear to have been affected by the soil gravel content and areas where the boreholes lacked N values, and, accordingly, where no liquefaction analyses were conducted.

In evaluating the liquefaction susceptibility in the Mint Canyon Quadrangle, the results were reviewed of the liquefaction analysis, interpretation of liquefaction susceptibility and zoning decisions made in the similar geologic units exposed in the adjacent Newhall Quadrangle.

Overall Liquefaction Susceptibility

The susceptibility of a deposit to liquefaction during future earthquakes was characterized by evaluating the deposit's depositional environment, texture and degree of compaction and cementation, the depth to ground water, and the quantitative liquefaction analyses. Pre-Quaternary bedrock geologic units are considered to have very low susceptibility.

From the 32 borehole logs with sufficient information, liquefaction analysis was conducted using the soil parameters collected for 206 of the soil samples. The logs indicate that gravel and/or cobbles were encountered in the strata that about 82% of the samples were collected from. Liquefiable sediments were identified in 38 samples from 14 of the boreholes with about 84% of the these samples being collected from strata containing gravel and /or cobbles. On the basis of the liquefaction analysis and re-analysis of the subsurface soils encountered in the boreholes and the interpreted Quaternary geology, the fluvial and alluvial flatland valley and fan deposits in the Mint Canyon Quadrangle with an historic shallow ground-water depth of less than 40 feet are considered to meet the liquefaction susceptibility zoning criteria under the applied ground motion. All the geologic units either were shown to contain liquefiable sediments by the liquefaction analysis, or were judged to potentially contain liquefiable sediments by correlation with adjacent units or similar units in other portions of the study area or because such units were of similar age and mode of deposition. Sufficient geotechnical data to fully analyze all the units in all portions of the study area were simply not available.

The Quaternary terrace deposits and the older colluvium mapped in the uplands of the study area are considered to be too consolidated and/or to be above the regional ground-water table and therefore do not meet the liquefaction susceptibility zoning criteria under the applied ground motion. Additionally, the small, scattered colluvium deposits were not included in the liquefaction zones because these deposits are above the regional ground-water table and are likely to be saturated only rarely.

Large artificial fills are judged to be recent enough to have been placed using modern grading codes and, therefore, are assumed to have a low liquefaction susceptibility. The liquefaction susceptibility for areas with artificial fill was based on the liquefaction susceptibility of the underlying natural geological unit.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.
2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.
3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.
4. Areas where existing geotechnical data are insufficient.

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Mint Canyon Quadrangle is summarized below.

Areas of Past Liquefaction

Although liquefaction resulting from the San Fernando earthquake of February 9, 1971 was not specifically identified in the quadrangle, the community of Solemint (now called Canyon Country) was described by Evans (1975, p. 143) as the "hardest hit of any community in the area." Solemint is only about 5 miles northwest of the epicenter and most structures in the area are on graded alluvium and, locally, the ground-water table is very shallow.

Following the Northridge earthquake of 1994, although ground ruptures and other liquefaction effects were identified at numerous localities along the Santa Clara River in the Newhall Quadrangle (Stewart and others, 1994), no direct observations of liquefaction-related ground-failure features were made in the Mint Canyon Quadrangle. Along Soledad Canyon Road in Canyon Country there were numerous water pipe breaks both east and west of Sierra Highway (Stewart and others, 1994, figure 4.64). Regardless of the uncertainty as to the direct cause of the breaks, because of the proximity of the breaks to the shallow ground-water saturated sediments along the Santa Clara River all of the localities are included within zones of required investigation for liquefaction.

Artificial Fills

Large artificial fills are judged to be recent enough to have been placed using modern grading codes and, therefore, are assumed to have a low liquefaction susceptibility. The liquefaction susceptibility for areas underlain by artificial fill was based on the liquefaction susceptibility of the underlying natural geological unit. Where fills were mapped across both alluvium and the adjacent bedrock, the liquefaction zone was extended over the alluvium only.

Areas with Sufficient Existing Geotechnical Data

Throughout the study area, the boreholes are grouped into a number of small, isolated and unevenly distributed concentrations, with only about 27% of the boreholes having sufficient information to conduct a liquefaction analysis. No boreholes were identified in most of the flatlands of the alluviated canyons. Therefore, for most of the study area the evaluation of liquefaction susceptibility of the alluvial flatlands is based on the interpreted geologic properties of the deposits rather than direct measurement. This interpretation is based on correlations between liquefaction susceptibility and the age and mode of deposition of the geologic deposits, supported by the results of the liquefaction analysis, interpretation of liquefaction susceptibility and zoning decisions made in the similar geologic units exposed in the adjacent Newhall Quadrangle and the depth to ground water. In summary, the study area does not contain sufficient areal distribution or density of boreholes, nor is the quality of data collected in this investigation from the existing boreholes sufficient to adequately evaluate the liquefaction susceptibility.

Areas with Insufficient Geotechnical Data

Bouquet Canyon and the tributary Texas Canyon, Vasquez Canyon, and Plum Canyon as well as the unnamed small tributary canyons contain several small, isolated and unevenly distributed concentrations of boreholes, although almost all have soil samples with N values and liquefaction analysis. These canyons are underlain by late Holocene fluvial and alluvial geologic units that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The ground-water table has been measured at a depth of generally less than 25 feet at the western margin of the study area in Bouquet Canyon and Plum Canyon, and measured or interpreted to be at a depth of less than 10 feet in most of Bouquet Canyon and in the tributary canyons. Liquefaction analysis of soil samples collected from half of the boreholes identified liquefiable sediments but the boreholes are too widely spaced or too shallow to adequately evaluate the liquefaction susceptibility of these areas. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Bouquet Canyon and the tributary Texas Canyon, Vasquez Canyon, and Plum Canyon, as well as the unnamed small tributary canyons, fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units, supplemented by the limited subsurface data and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

In Haskell Canyon and its unnamed tributary canyon no borehole information was obtained. These canyons are underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The interpreted depth to ground water is about 25 feet. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Haskell Canyon and its unnamed tributary canyon fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

Mint Canyon has only a few boreholes in the far southern portion of the canyon and none with N values and liquefaction analysis. Baker Canyon and its tributary canyons contain no boreholes. These canyons are underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The measured depth to ground water in Mint Canyon, Baker Canyon and the tributary canyons is generally less than 10 feet but descends to as much as 25 feet in Sections 1, 2, 35, and 36. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Mint Canyon, Baker Canyon, and its tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the measured shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units, supplemented by the limited subsurface data and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

The Santa Clara River Valley, Tick Canyon, Oak Spring Canyon and the moderate-size, unnamed tributary canyons contains several small, isolated and unevenly distributed concentrations of boreholes. However, only a few of these have soil samples with N values and liquefaction analysis. This area is underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The ground-water table has been measured at a depth of generally less than 15 feet in the Santa Clara River Valley and is generally interpreted to be at a depth of less than 25 feet in Tick Canyon and Oak Spring Canyon, as well as the unnamed tributary canyons. Less than half of the small number of boreholes with liquefaction analyses encountered liquefiable sediments but the boreholes are too widely spaced or too shallow to adequately evaluate the liquefaction susceptibility of these areas. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, the Santa Clara River Valley, Tick Canyon, Oak Spring Canyon, and the moderate-size, unnamed tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the measured shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units, supplemented by the limited subsurface data and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

In Sand Canyon, Iron Canyon, Gorman Canyon, Coyote Canyon, and Bear Canyon and the small tributary canyon no boreholes were located. These canyons are underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The interpreted depth to ground water is generally less than 25 feet. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Sand Canyon, Iron Canyon, Gorman Canyon, Coyote Canyon, and Bear Canyon and the small tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

In Placerita Canyon there are only a few boreholes in the far western portion of the canyon and none with N values and liquefaction analysis. This canyon is underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The depth to ground water in most of the canyon, as well as the tributary canyon in Section 32 is generally measured or interpreted to be less than 10 feet. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Placerita Canyon and its small tributary canyon fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

In Quigley Canyon, the large exposures of slopewash to the east of Placerita Canyon, and the small alluvial canyons along the western and eastern quadrangle boundaries, no boreholes were located. These canyons are underlain by late Holocene fluvial and alluvial geologic deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The depth to ground water in the slopewash and small alluvial canyons is interpreted to be about 10 to 20 feet. In Quigley Canyon, the depth to ground water is interpreted to be less than 40 feet. These areas are underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Quigley Canyon, the large exposures of slopewash to the east of Placerita Canyon and the small alluvial canyons along the western and eastern quadrangle boundaries fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Mint Canyon 7.5-Minute Quadrangle, Los Angeles County, California

By

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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Mint Canyon 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Typically, areas most susceptible to earthquake-induced landslides are on steep slopes and on or adjacent to existing landslide deposits, especially if the earth materials in these areas are composed of loose colluvial soils, or poorly cemented or highly fractured rock. These geologic and terrain conditions exist in many parts of southern California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the Mint Canyon Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus the quality of the data is variable. Although selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Mint Canyon Quadrangle for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide susceptibility and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Mint Canyon Quadrangle covers approximately 62 square miles of land in west-central Los Angeles County. Parts of the City of Santa Clarita, including the communities of Newhall and

Canyon Country that lie primarily west of the Antelope Valley Freeway (State Highway 14), cover the central and western portion of the quadrangle. The city also extends to an area that straddles Sand Canyon Road, south of the freeway. Canyon Country (Solemint Junction), near the center of the quadrangle, lies about 27 miles north-northwest of the Los Angeles Civic Center. The remainder of the land within the quadrangle is either comprised of unincorporated county land or lies within the Angeles National Forest, except for a small part of Placerita Canyon State Park that lies along the southern boundary. The primary access to the area is via the Antelope Valley Freeway (State Highway 14), which crosses the quadrangle from the southwestern corner to the eastern boundary. East of Solemint Junction, which is located near the freeway crossing of the Santa Clara River, the freeway follows the course of the river, which flows across the center of the quadrangle. West of Solemint Junction, Soledad Canyon Road provides access from Saugus to the west. Sierra Highway, which follows Mint Canyon, crosses the entire quadrangle from southwest to northeast.

The topography of the quadrangle is dominated by irregular, mountainous, brush-covered terrain. Numerous canyons dissect the mountains. Some of the larger canyons, such as Sand, Mint, and Tick canyons, are tributary to the Santa Clara River. Bouquet Canyon, which itself has tributaries including Texas, Vasquez, and Plum canyons, exits the quadrangle in the central part of the western boundary and joins the Santa Clara River in the Newhall Quadrangle. Placerita Canyon lies close to the southern boundary of the quadrangle.

Residential and commercial development, primarily of the lower-lying canyon-bottom lands, has replaced agricultural and grazing land uses within the area in recent decades. Modern development is characterized by mass grading of the hillside areas at a large scale. The remainder of the area is largely unoccupied, although agricultural activities, small ranches, oil fields, parkland, and National Forest lands are scattered across the quadrangle.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

For the Mint Canyon Quadrangle, a recently compiled geologic map was obtained from the U.S. Geological Survey (USGS) in digital form (Yerkes, 1996). Yerkes (1996) compiled and digitized the large-scale geologic maps of Saul and Wootton (1983) and Saul (1985). Other geologic maps reviewed for this project include: Oakeshott (1958), Winterer and Durham (1962), Weber (1982), and Dibblee (1996). The digital geologic map was modified to reflect the most recent mapping in the area. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of slope failures was noted.

The oldest rocks in the Mint Canyon Quadrangle are a Precambrian gabbro (gb) bordering a large norite-anorthosite basement complex exposed north of the San Gabriel Fault. Assorted pre-Cenozoic gneissic (gn), granitic rocks (gr) and, locally, Pelona Schist (ps) are exposed along the northern boundary of the quadrangle. South of the San Gabriel Fault, the oldest units consist of

Placerita Formation metasedimentary rocks (pm) of possible Paleozoic age that have been intruded by Cretaceous granodiorite (gd).

The oldest rocks of the sequence of sedimentary and volcanic rocks that rests upon the basement rocks belong to the Vasquez Formation (Tvz) of Oligocene age, which consists of non-marine red beds and fan deposits of gritty siltstone, sedimentary breccia, claystone, mudstone, and limestone and small amounts of andesitic volcanic rocks (Tvv). Tick Canyon Formation (Ttk) of early Miocene age rests unconformably upon the Vasquez Formation and consists mostly of poorly consolidated conglomeratic sandstone and lesser siltstone of fluvial origin.

The middle to late Miocene Mint Canyon Formation (Tmc) rests unconformably upon the Tick Canyon Formation and is the most widespread Tertiary formation in the quadrangle. The Mint Canyon Formation is predominantly a lacustrine and fluvial sequence that contains several coeval facies. They are, as subdivided by Saul and Wootton (1983): Tmc1- a marginal facies that consists of arkosic sandstone and conglomeratic sandstone, with minor siltstone and silty clay shale; Tmc2 - a bottomset facies containing interbedded claystone, siltstone, silty sandstone, and sandstone and minor conglomerate and limestone; Tmc3 - a deltaic facies that includes arkosic sandstone, sandy conglomerate, interlayered sandy siltstone and claystone, and tuff beds (T). Overlying the Mint Canyon Formation in the northwest corner of the map area and near the San Gabriel Fault is the late Miocene Castaic Formation (Tcs), which consists of shallow marine sandstone and shale distinguishable by the large variety of mollusk species from the late Miocene. Coevally deposited with the Castaic Formation, the late Miocene to early Pliocene Towsley Formation (Tw and Twc), which consists of interbedded marine siltstone, sandstone, and conglomerate, crops out in slivers along the San Gabriel Fault in the southwestern corner of the map area.

The Plio-Pleistocene nonmarine Saugus Formation rests unconformably upon the Towsley Formation. The Saugus Formation consists of a lower unit, the Sunshine Ranch Member (Tsr) of Pliocene age, that has an upper facies (Tsru), mapped only north of the San Gabriel Fault, comprised of sandy siltstone, mudstone, and pebbly and sandy conglomerate and an lower facies (Tsrl) of arkosic sandstone, pebbly sandstone, and conglomerate. The Pleistocene unnamed upper member of the Saugus Formation (Qs) consists of nonmarine arkosic sandstone, sandy conglomerate, sandy siltstone, and claystone. Locally, an upper, coarse-grained, facies (Qsc) of poorly consolidated sandstone and sandy conglomerate and a basal conglomerate (Qsg) are mapped separately. The Pleistocene Pacoima Formation (Qpa), rests unconformably upon the Saugus Formation and consists of a nonmarine unit that ranges from silty sandstone to pebble-boulder conglomerate and is only present south of the San Gabriel Fault.

Quaternary units, such as terrace deposits (Qt), older colluvium (Qco), and fan deposits (Qf) consist of poorly consolidated interbeds of sand, silt, and gravel. Terrace deposits unconformably overlie the Saugus Formation primarily north of the Santa Clara River near the western edge of the map and Mint Canyon Formation on Cruzan Mesa, between Mint Canyon and Bouquet Canyon, and west of Bouquet Canyon.

Younger Quaternary surficial deposits, including units mapped as floodplain deposits (Qfp) and alluvium (Qal) cover the floors of the Santa Clara River Valley, Bouquet Canyon, Haskell Canyon, Texas Canyon, Vasquez Canyon, Plum Canyon, and the northern part of Mint Canyon. The floors of most of the unnamed tributary canyons, as well as Baker Canyon, Sand Canyon, Iron Canyon, much of Oak Spring canyon, the southern part of Mint Canyon, and Placerita Canyon are mapped as colluvium (Qc), which includes sheet wash, rock debris, and overbank deposits that consist of sand, silt, and clay. These deposits extend up into the canyons in the surrounding hills and mountains. Locally, slope wash deposits (Qsw) and pond deposits (Qp) have been mapped. Landslide deposits (Qls) are particularly abundant in the southwestern quarter of the quadrangle where they rest upon Mint Canyon and Saugus formation rocks. Modern man-made fill (af) or artificial cut and fill (afc) are mapped in some areas where development involved massive grading or along the freeway roadbed. A more detailed discussion of the Quaternary deposits in the Mint Canyon Quadrangle can be found in Section 1.

Geologic Structure

The northwest-striking San Gabriel Fault, which crosses the southwestern corner of the Mint Canyon Quadrangle, is the dominant structural feature in the area. Other structurally important faults, the Agua Dulce, Soledad, and Pole Canyon faults are either exposed in the basement terrain or inferred to lie beneath the Santa Clara River floodplain. In the western half of the quadrangle, most faults and fold axes, as well as the strike of bedding of the pre-Quaternary rock units, trend subparallel to the strike of the San Gabriel Fault. In the eastern half of the quadrangle, east of Mint Canyon and Sand Canyon, the pre-Quaternary rock units strike northeast-southwest to north-south and dip to the west. Throughout the quadrangle, dips in the pre-Quaternary units are generally less than 45 degrees. Locally, steeply dipping bedrock (> 45º) exists, primarily south of the Santa Clara River and adjacent to the San Gabriel Fault zone.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they must first be ranked on the basis of their overall shear strength. Shear strength data for the rock units identified on the geologic map were obtained from a variety of sources (see Appendix A). The primary source for rock shear strength measurements is geotechnical reports prepared by consultants on file with the local government permitting departments. Geotechnical and engineering geologic reports contained in Environmental Impact Reports and Hospital Review Project files at DMG are additional sources. Where no shear strength data was available for very hard rock units, such as granitic rocks in the Mint Canyon Quadrangle, a number was assigned based on field observations and select rock mechanics data sources (Hoek and Bray, 1981; Jumikis, 1983). Where shear strength information was lacking for certain rock units within the Mint Canyon Quadrangle itself, it was collected from adjacent areas. The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above sources were compiled for each mapped geologic unit, and subdivided for fine-grained and coarse-grained lithologies, if appropriate. Geologic units were grouped on the basis of average angle of internal friction (average f) and lithologic character. Geologic formations that had little or no shear test information were added to existing groups on the basis of lithologic and stratigraphic similarities.

To subdivide mapped geologic formations that have both fine-grained and coarse-grained lithologies, we assumed that where stratigraphic bedding dips into a slope (favorable bedding) the coarse-grained material strength dominates, and where bedding dips out of a slope (adverse bedding) the fine-grained material strength dominates. We then used structural information from the geologic map (see "Structural Geology") and terrain data in the form of slope gradient and aspect, to identify areas with a high potential for containing adverse bedding conditions. These areas, located on the map, were then used to modify the geologic material-strength map to reflect the anticipated lower shear strength for the fine-grained materials.

The results of the grouping of geologic materials in the Mint Canyon Quadrangle are in Tables 2.1 and 2.2.

Structural Geology

Accompanying the digital geologic map (Yerkes, 1996) were digital files of associated geologic structural data, including bedding and foliation attitudes (strike and dip) and fold axes. We used the structural geologic information provided with the digital geologic map (Yerkes, 1996), supplemented by structural geology from Saul and Wootton (1983), to categorize areas of common stratigraphic dip direction and magnitude, similar to the method presented by Brabb (1983). The dip direction category was compared to the slope aspect (direction) category and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, and the bedding dip was greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area. This information was then used to subdivide mapped geologic units into areas where fine-grained and coarse-grained strengths would be used.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of the existing landslides in the entire Mint Canyon Quadrangle was prepared using interpretation of stereo-paired aerial photographs of the study area (see Air Photos in References) and limited field reconnaissance, Haydon (unpublished). All areas containing landslides identified in the previous work (Saul and Wootton, 1983; Saul, 1985) were reevaluated during the aerial photograph interpretation conducted for this investigation. Some of the landslides identified in the previous work were not included in the landslide inventory because in our reevaluation it was concluded that the feature was not a landslide. Many additional landslides were identified and boundaries of many of the landslides shown in previous work were modified. Additionally, all landslides shown on the digital geologic map (Yerkes, 1996) were verified, remapped or removed during preparation of the inventory map. The completed hand-drawn landslide map was scanned, digitized and the database was attributed with landslide information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). To keep the landslide inventories of consistent quality, all landslides originally depicted on the digitized geologic map were deleted and only those included in the DMG inventory were incorporated into the hazard-evaluation process. A version of this landslide inventory is included with Plate 2.1.

MINT CANYON QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number of Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1						gr, gb, gd	40
GROUP 2	Tmc3(fbc) Tmc1(fbc) Tcs(fbc) Tsrl(fbc) Tsru(fbc) Qsc(fbc)	52 3 12 4 20 3	34/34 35/34 37/37 35/37 36/35 37/37	35/35	449/300	pm, ps, gn Tvz(fbc), Tvv(fbc) T(fbc) Tw(fbc) Twc(fbc) Qsg(fbc)	35
GROUP 3	Ttk(fbc) Tmc2(fbc) Qs(fbc)	10 23 35	32/32 31/31 31/30	31/31	404/322		31
GROUP 4	Qs(abc) Qt Qal af	17 12 88 10	27/25 28/30 28/30 28/27	28/28	310/249	Qsg(abc),Qsc(abc) Qpa, Qco, Qf Qfp, Qsw Qc, afc	28
GROUP 5	Ttk(abc) Tmc3(abc) Tmc2(abc) Tmc1(abc) Tcs(abc) Tsrl(abc) Tsru(abc)	11 36 31 2 9 4 24	25/24 25/26 23/23 25/25 23/21 22/25 25/25	24/24	629/455	Tvz(abc) Tvv(abc) T(abc) Tw(abc) Qp	24
GROUP 6	Qls	16	16/15	16/15	390/253		16

abc=adverse bedding condition, fine-grained material strength
fbc=favorable bedding condition, coarse-grained material strength

Table 2.1. Summary of the shear strength statistics for the Mint Canyon Quadrangle.

SHEAR STRENGTH GROUPS FOR THE MINT CANYON QUADRANGLE					
GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**	**GROUP 5**	**GROUP 6**
gr gb gd	pm ps gn Tvz(fbc) Tvv(fbc) T(fbc) Tmc3(fbc) Tmc1(fbc) Tcs(fbc) Tw(fbc) Twc(fbc) Tsrl(fbc) Tsru(fbc) Qsg(fbc) Qsc(fbc)	Ttk(fbc) Tmc2(fbc) Qs(fbc)	Qs(abc) Qsg(abc) Qsc(abc) Qpa Qt Qco Qf Qfp Qsw Qc Qal afc af	Tvz(abc) Tvv(abc) Ttk(abc) T(abc) Tmc3(abc) Tmc2(abc) Tmc1(abc) Tcs(abc) Tw(abc) Tsrl(abc) Tsru(abc) Qp	Qls

Table 2.2. Summary of the shear strength groups for the Mint Canyon Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the Mint Canyon Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.6 to 7.8
Modal Distance:	2.5 to 21.9 km
PGA:	0.5 to 0.9 g

Based on the range in modal magnitude and distance, two potential strong-motion records with different source magnitudes and distances were evaluated to determine the greatest potential

Newmark displacements in the Mint Canyon Quadrangle: 1) a simulated San Andreas fault event of 8.0 Mw at 30 km (Paul Sommerville, personal communication), and 2) the USC Station #14 record (Trifunac and others, 1994) from the 1994 Northridge earthquake of 6.7 Mw at 8.5 km.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion records were integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). We determined that the smaller, near-field event (Northridge earthquake) produced greater Newmark displacements and, therefore, would provide a better, conservative evaluation. The selected strong-motion record had a peak ground acceleration of 0.59g and was not scaled or otherwise modified prior to analysis.

The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Mint Canyon Quadrangle.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Mint Canyon Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the topographic contours constructed in 1960 for the 7.5-minute quadrangle map, has a 10-m horizontal resolution and a 7.5-m vertical accuracy. Surrounding quadrangle DEMs were merged with the Mint Canyon DEM to avoid the loss of data at the quadrangle edges when the slope calculations were performed. A peak and pit smoothing process was then performed to remove errors in the elevation points.

Areas that have recently undergone large-scale grading projects since 1960 as a part of residential development were identified on aerial photography flown in the winter and spring of 1994. Terrain data for these areas were obtained from an airborne interferometric radar (TOPSAR) DEM flown and processed in August 1994 by NASA's Jet Propulsion Laboratory (JPL), and reprocessed by Calgis, Inc (GeoSAR Consortium, 1995 and 1996). These terrain data were also smoothed prior to analysis. Plate 2.1 shows those areas where the topography is updated to 1994 grading conditions.

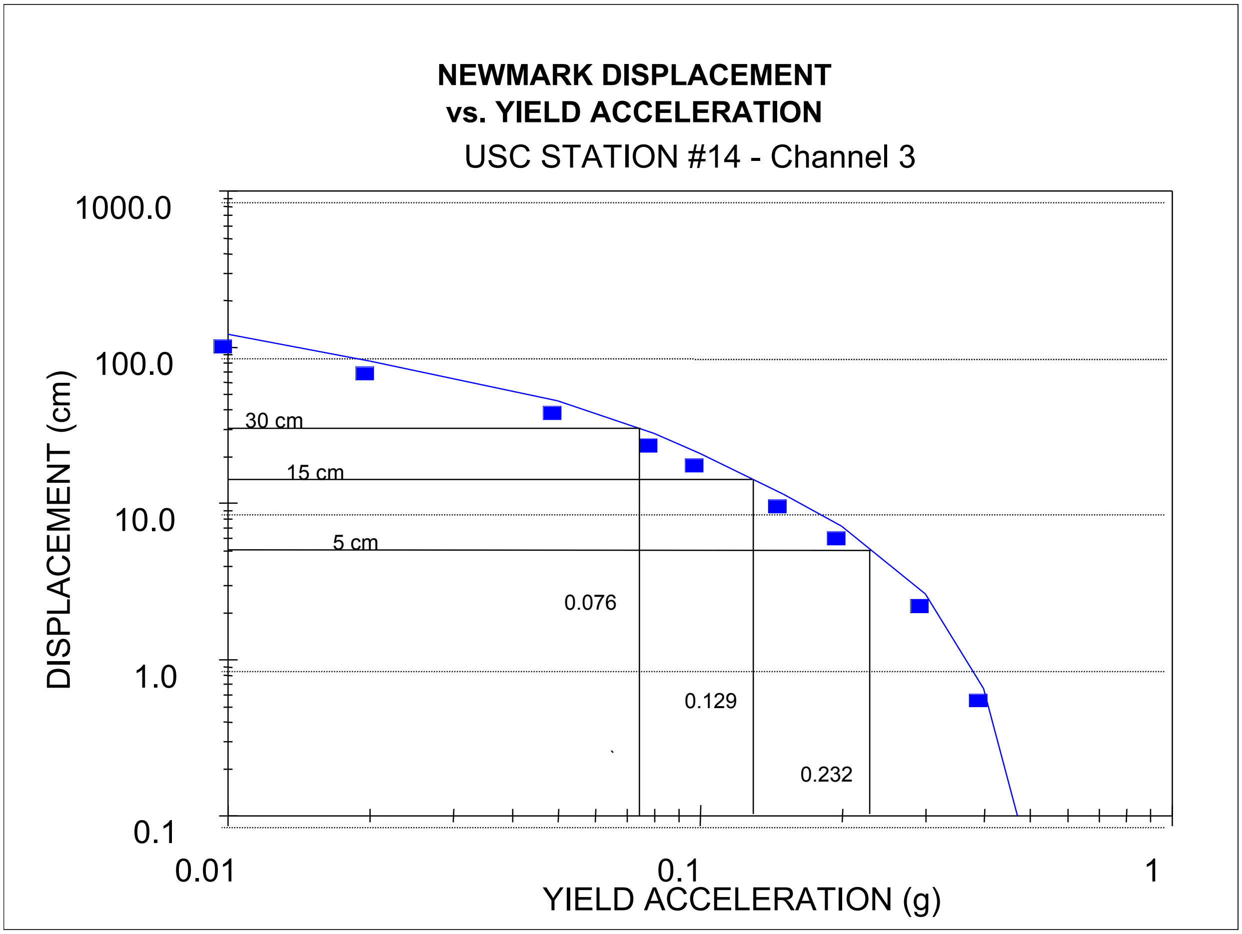

Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station # 14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

Slope-gradient maps were made from the DEMs using a third-order finite-difference center-weighted algorithm (Horn, 1981). The DEMs were then used to make slope-aspect maps. The slope-gradient maps were used first in conjunction with the aspect maps and geologic structural data to identify areas of potential adverse bedding conditions, and then again with the geologic strength map in the preparation of the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of one degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle. Based on the susceptibility criteria described above, if the calculated yield acceleration was less than 0.076g, expected displacements could be greater than 30 cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129g a MODERATE (M on Table 2.3) potential was assigned, between 0.13 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide susceptibility map was prepared by combining the geologic material-strength map and the slope map according to this table.

MINT CANYON QUADRANGLE HAZARD POTENTIAL MATRIX											
		SLOPE CATEGORY									
Geologic Material Group	Mean Phi	I 0-20%	II 21-24%	III 25-30%	IV 31-35%	V 36-40%	VI 41-45%	VII 46-56%	VIII 57-66%	IX 67-72%	X >72%
1	40	VL	VL	VL	VL	VL	VL	VL	L	M	H
2	35	VL	VL	VL	VL	VL	VL	L	M	H	H
3	31	VL	VL	VL	VL	L	L	M	H	H	H
4	28	VL	VL	VL	L	L	M	H	H	H	H
5	24	VL	L	L	M	H	H	H	H	H	H
6	16	L	M	H	H	H	H	H	H	H	H

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the Mint Canyon Quadrangle. Shaded area indicates the hazard potential levels included in the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, earthquake-induced landslide zones are areas meeting one or more of the following:

1. Areas known to have experienced earthquake-induced slope failure during historic earthquakes.

2. Areas identified as having past landslide movement, including both landslide deposits and source areas.

3. Areas where CDMG's analyses of geologic and geotechnical data indicate that the geologic materials are susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

The February 9, 1971 San Fernando earthquake likely triggered numerous rockfalls and debris falls in the portion of the San Gabriel Mountains that extends into the southern part of the Mint Canyon Quadrangle (Evans, 1975). These shallow failures were only referred to in general descriptions of the effects of the event and have not been delineated on any maps. The 1994 Northridge earthquake also caused a number of relatively small, shallow slope failures in the Mint Canyon Quadrangle (Harp and Jibson, 1995). Landslides attributed to the Northridge earthquake covered approximately 104 acres of land in the quadrangle, which is less than 1/2 of 1 percent of the total area covered by the map. Of the area covered by these Northridge earthquake landslides, 83% falls within the area of the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the high, moderate and low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 5 is always included in the zone (mapped landslides Qls); strength group 4 is in the zone for all slopes greater than 20%;

strength group 3 above 30%; strength group 2 above 35%; and strength group 1 above 45%. This results in roughly 28% of the land in the Mint Canyon Quadrangle, including National Forest Service land, lying within the hazard zone.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. Geologic material strength data were collected at the Los Angeles County Department of Public Works with the assistance of Robert Larson, James Shuttleworth, Charles Nestle, and Dave Poplar. Digital terrain data and assistance were provided by Randy Jibson of the U.S. Geological Survey (USGS DEM), Scott Hensley of JPL, and Gerald Dildine and Chris Bohain of Calgis, Inc. (Radar DEM). Technical review of the methodology was provided by Bruce Clark, Randy Jibson, Robert Larson, Scott Lindvall, and J. David Rogers, who are members of the State Mining and Geology Board's Seismic Hazards Mapping Act Advisory Committee Landslides Working Group. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Barbara Wanish, and Scott Shepherd for their Geographic Information System operations support, and to Barbara Wanish for preparing the graphic displays associated with the hazard zone map and this report.

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APPENDIX A
SOURCES OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County Department of Public Works	**412**
Geotechnical reports from environmental impact documents and DMG staff on file at DMG	**10**
Total number of tests used to characterize the units in the Mint Canyon Quadrangle	**422**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Mint Canyon 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark D. Petersen, Chris H. Cramer, Geoffrey A. Faneros, Charles R. Real and Michael S. Reichle

California Department of Conservation Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple

Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

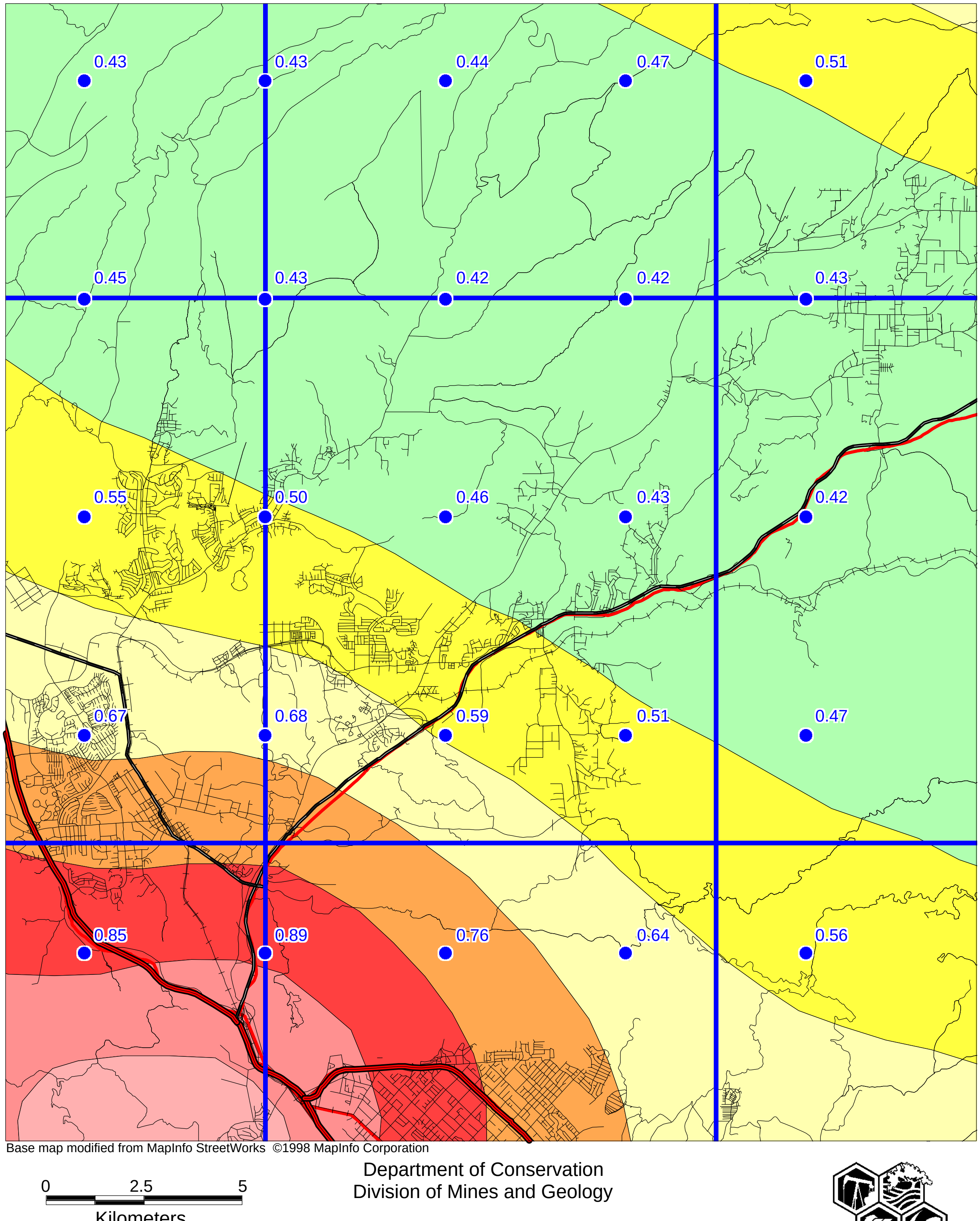
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

MINT CANYON 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Department of Conservation
Division of Mines and Geology

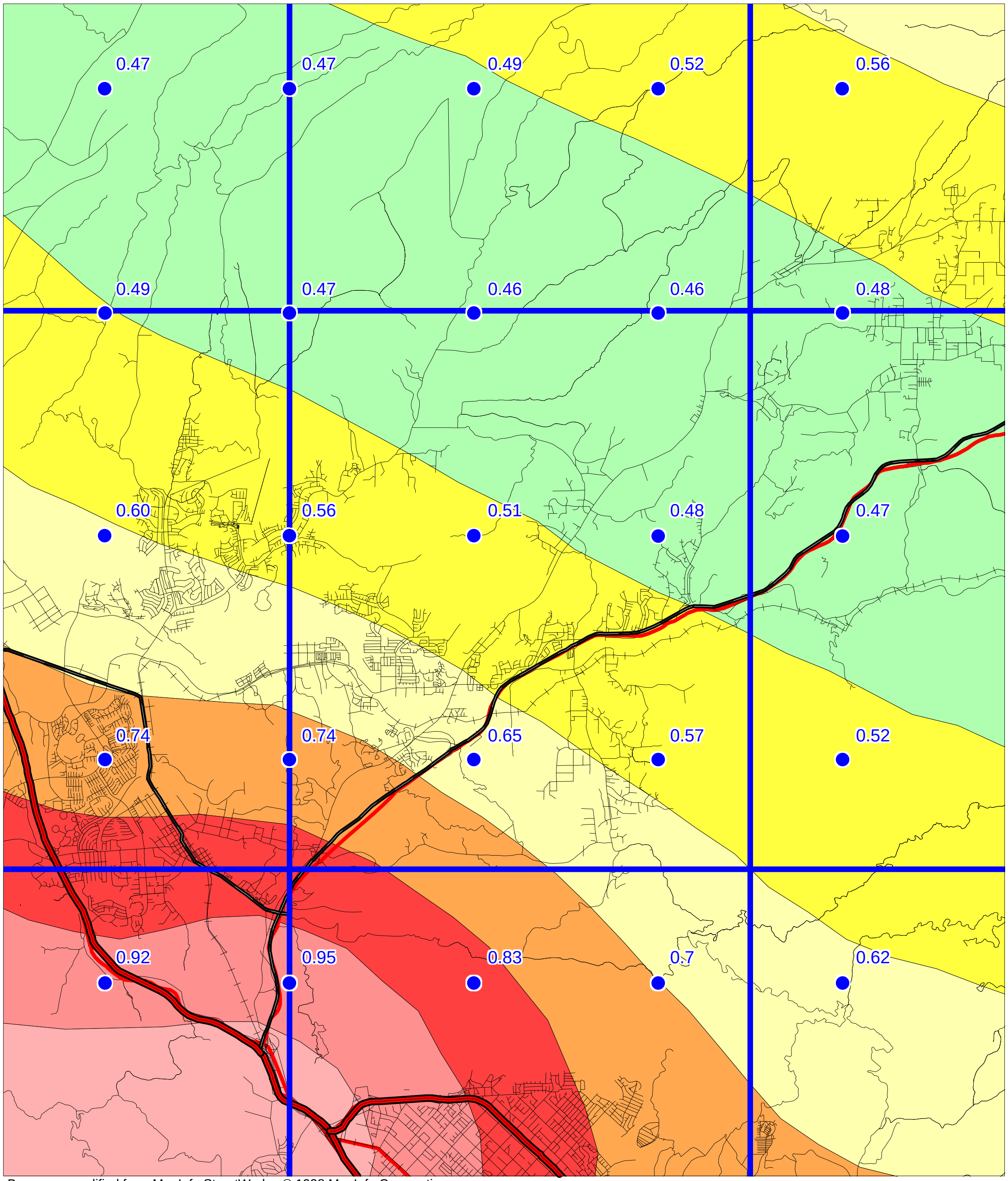
Figure 3.1

MINT CANYON 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

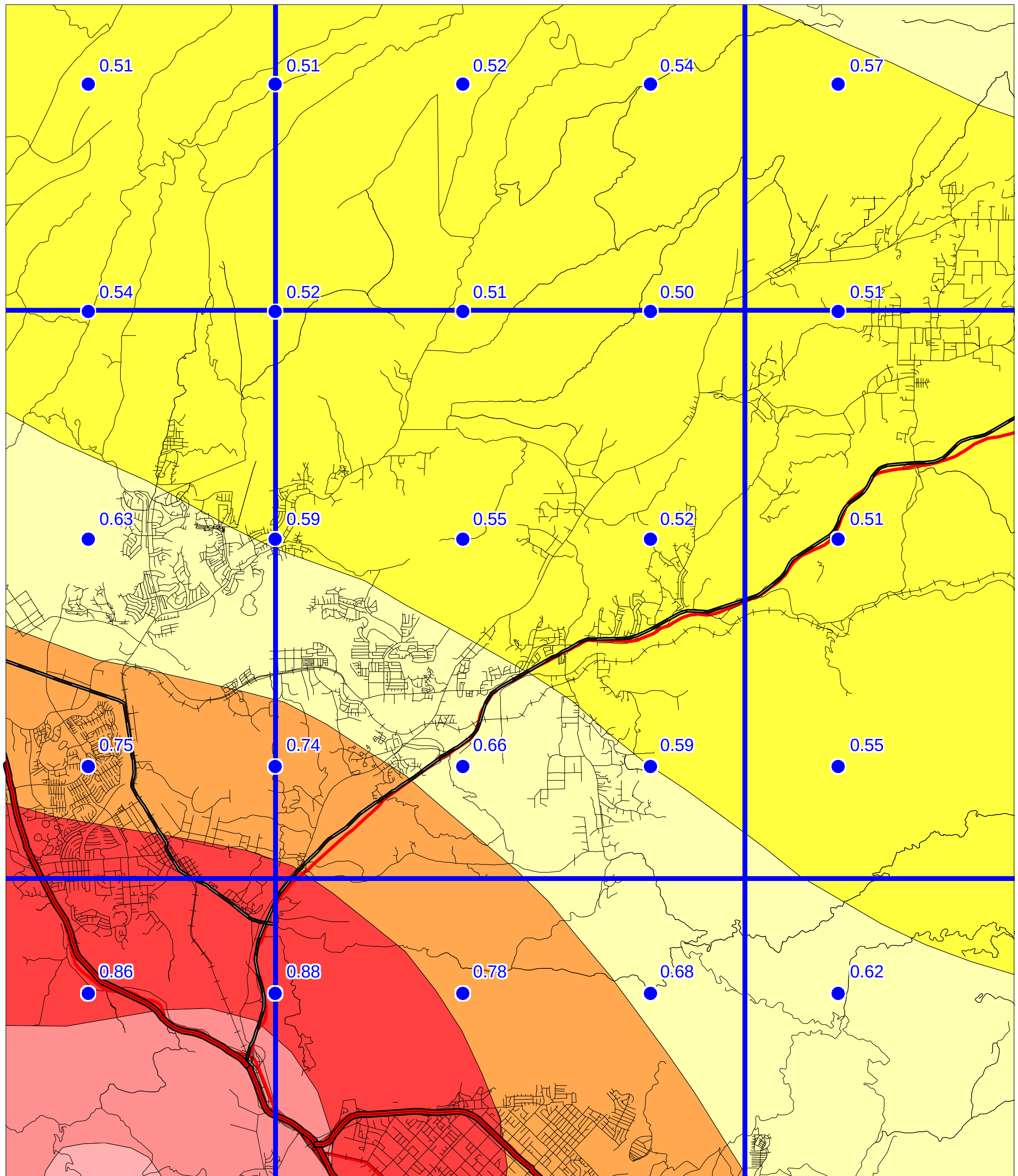
Figure 3.2

MINT CANYON 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

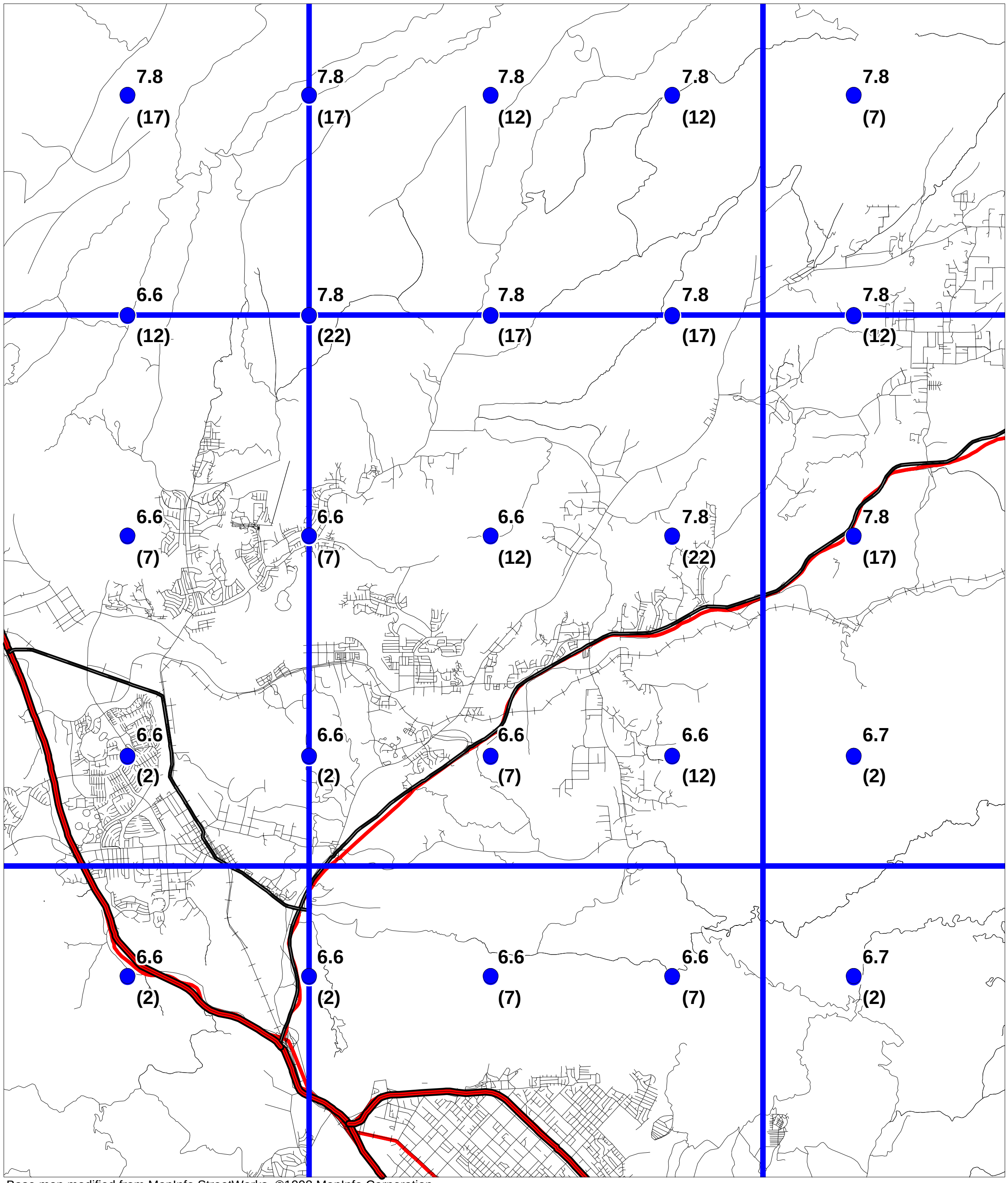
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual

MINT CANYON 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.4

ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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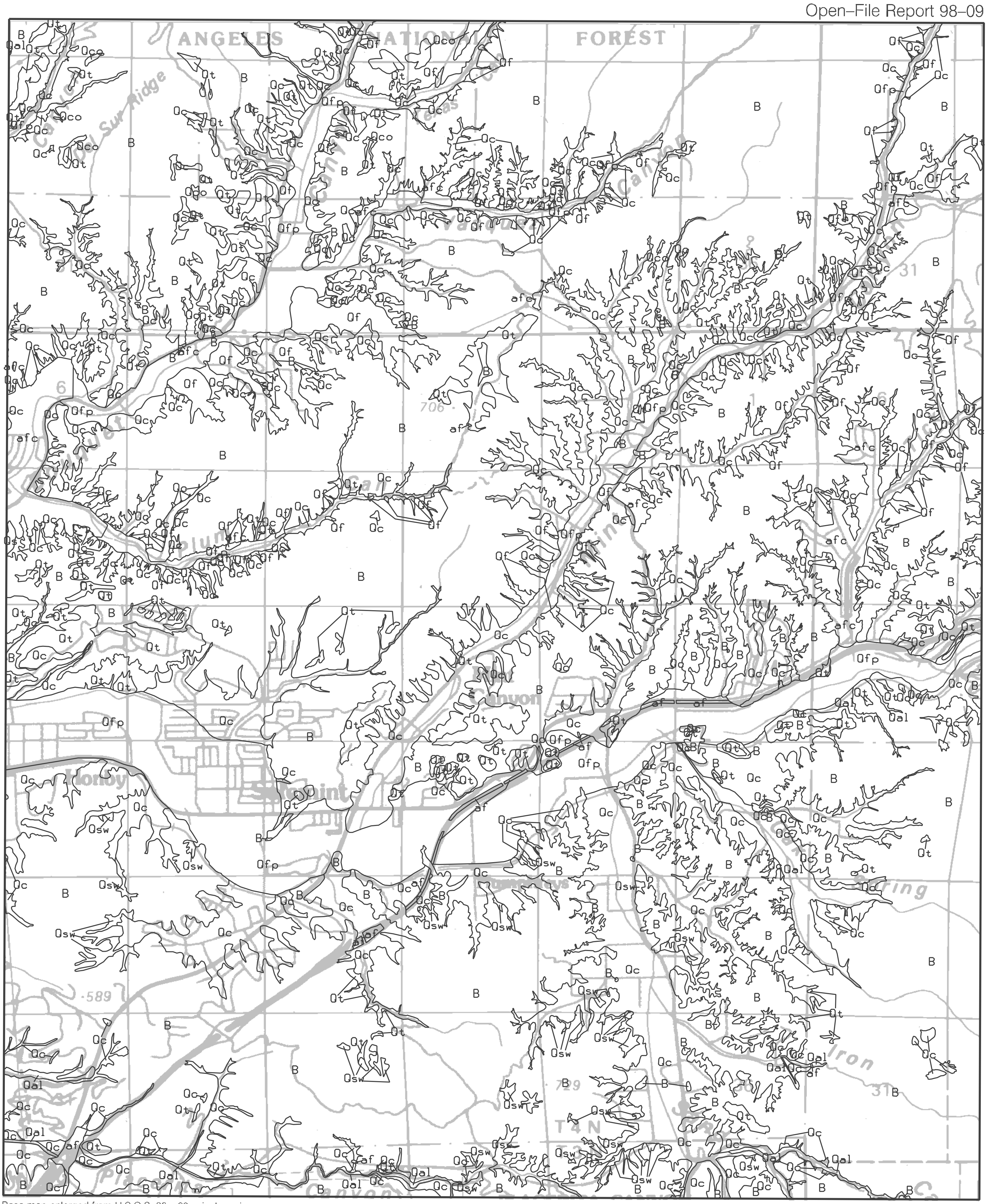


Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.1 Quaternary Geologic Map of the Mint Canyon Quadrangle

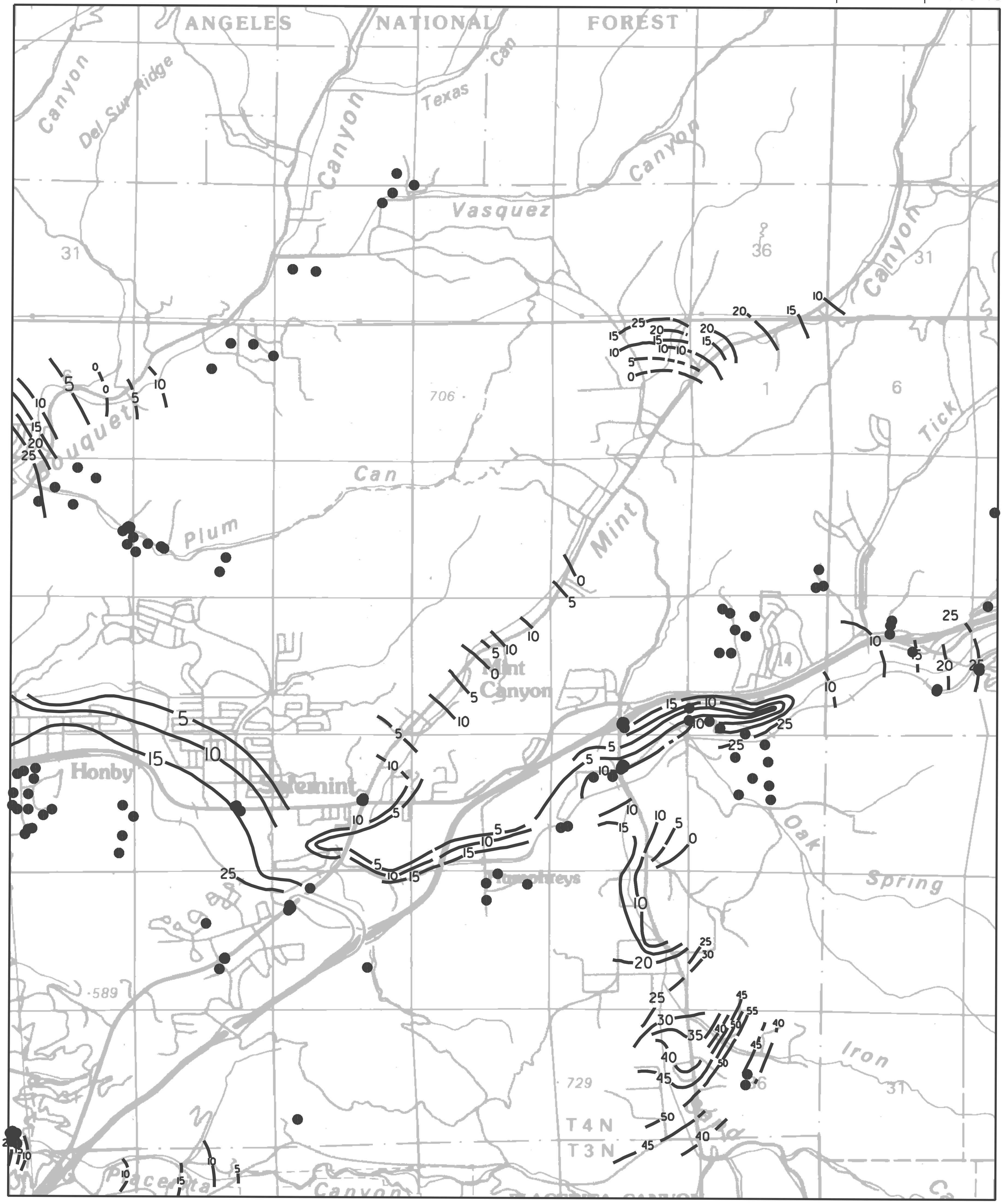
See Geologic Conditions section in report for descriptions of the units.

B = Pre–Quaternary bedrock.

afc	Artificial Fill or Cut–Undifferentiated	Qf	Fan Deposits
af	Artificial Fill	Qfp	Flood Plain Deposits
Qal	Undifferentiated Alluvium	Qt	Terrace Deposits
Qc	Colluvium	Qco	Older Colluvium
Qsw	Slope Wash Deposits		

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

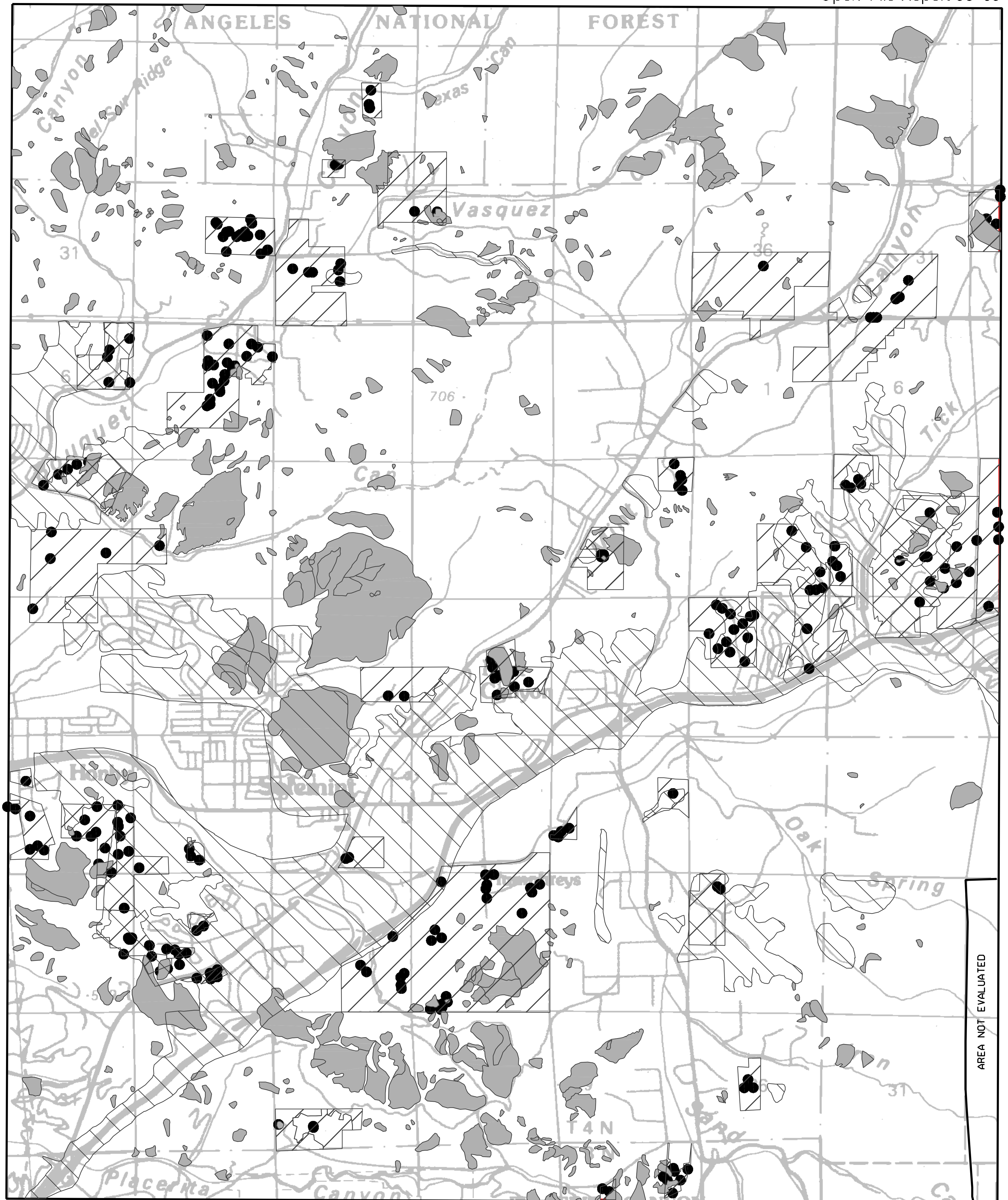
Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Mint Canyon Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide Inventory, Shear Test Sample Locations, and Areas of Significant Grading, Mint Canyon Quadrangle.

shear test sample location
landslide
area of significant grading
tract report with multiple shear tests

ONE MILE
SCALE